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Criticality Safety: Early Accidents at Los Alamos

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NEN-2: Advanced Nuclear Technology

August 28, 2020

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ABSTRACT

The results of an experiment can never be considered a failure. Analyses of the results often suggest modifications to theories and procedures to improve the understanding of the underlying principles. In a similar way, observation and analyses of accidents suggest modifications to procedures and behavior to minimize repetition.

Although I have worked in the field for over fifty years, I do not feel that I have been accepted by the Criticality Safety Community – because…

Although I have worked in the field for over fifty years, I do not feel that I have been accepted by the Criticality Safety Community – because…

I have spent a large portion of my life making systems critical – rather than keeping systems from going critical!

Nevertheless, it has been my privilege to have worked with **GIANTS**…

Hugh Paxton
Dixon Callihan
Gordon Hansen
John Orndoff
Bob Keepin
Bob Long
Bob Jefferson
Gene Plassmann
Dave Smith
Raemer Schreiber
and others….

ALWAYS REMEMBER --

You don’t

Plan

To Have An ***Accident***!

BECAUSE

An Accident is an UNPLANNED Event

Ac-ci-dent

1. An unexpected and undesirable event.

2. Something that occurs unexpectedly or unintentionally

3. A circumstance or attribute that is not essential to the nature of something.

4. Fortune or chance

What I would like to have you take from my presentation:

Neither the Code of Federal Regulations, ANSI Standards, DOE Orders, nor even training **prevents** ACCIDENTS!

Safety is a state of mind, attention to detail, and a result of experience…

Although you cannot teach safety, you can study the lessons of the past and avoid repeating the environment that has resulted in accidents!

In considering the details of the following three accidents, I would like to make them personal by putting us in the position of the participants.

Where do you find the cross-sections to use for your calculations?

How accurate are they?

Nevertheless, results of calculations are often reported to four or more significant figures.

How does your computer program treat the n-2n reaction in beryllium?

Is it important to know this?

Is the k_{eff} resulting from that treatment of the n-2n reaction correct?

Nuclear reactions occur in a time frame of micro-sec.

How long is a micro-sec?

There are 86,400 seconds in a day.

Round that off to 100,000 sec./day

There are approximately 1,000,000 seconds in 10 days

The relationship of a micro-sec. to a second is about the same as the relationship of a second to ten days!

0.000001/1.0 = 1.0/1,000,000

What is the best reflector for a fast system?

- Water
- Tungsten Carbide
- Beryllium
- Steel

Is the human body a good reflector?

What is the only element in the periodic table that cannot 180 deg backscatter?

How many collisions are required for a neutron to be returned from a water reflector?

What is the average solid angle subtended by a sphere in a close fitting box?

One of the most difficult calculations to make is the kinetic reaction of a solution of fissionable material.

Why?

The reaction is affected by the formation of radiolytic bubbles of gas that reduce local density, modify the power density distribution, alter the chemical composition, and migrate out of the solution.

We could spend all week exploring the phenomena!

All of that being said, please:

Close your notes, and turn off your cell phones.

You are limited to using a slide rule, pencil, nuclear cross-sections that you have measured or can infer from work on the Water Boiler, and a table of logarithms to evaluate kinetics of the following reactions in fast systems.

It is late 1944 leading into the first months of 1945. We are familiar with the results from the Chicago Pile, the X-10 Reactor at Oak Ridge, and the Water Boilers at Los Alamos.

However, there has never been a demonstration of a chain reaction sustained by prompt neutrons alone, and the cross-sections for fast fission are not well known.

With that in mind, a proposal was made by Otto Frisch to construct and operate a machine to demonstrate a nuclear reaction sustained by prompt fissions alone.

When the proposal was described to a Safety Committee including Enrico Fermi and Dick Feynman, the latter observed that this…

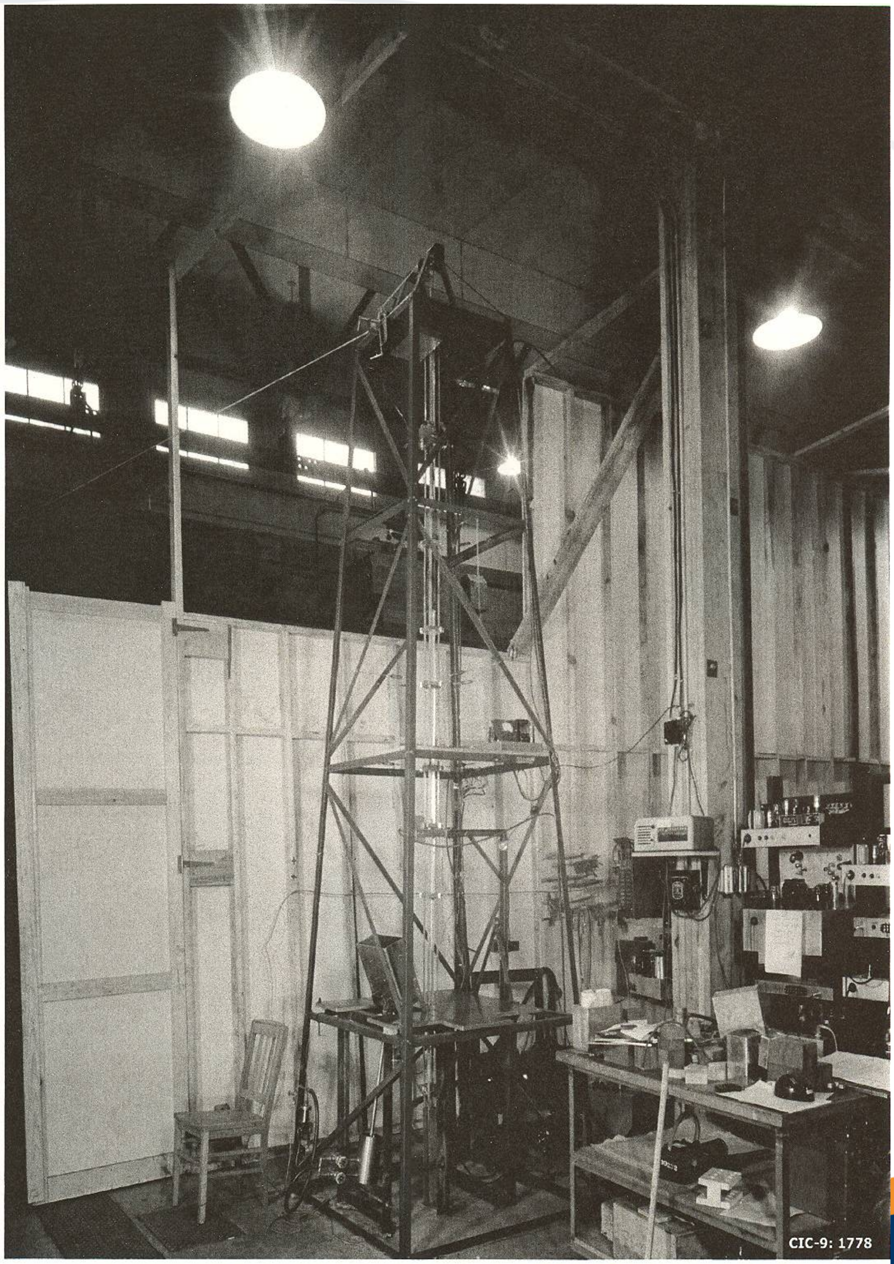
“was just like tickling the tail of a sleeping dragon”

Hence, the machine became known as The Dragon

"A chain reactor (The "Dragon") was constructed so that by dropping a slug through an assembly (both of active material), a divergent chain reaction supported by prompt neutrons alone was achieved for about 1/1000 second. In this short time neutron multiplications up to 10^{12} were obtained. Various measurements were made which permitted calculation of the generation time in two independent ways; from the shape, and from the size of the neutron burst which occurred when the system became prompt neutron supercritical; these calculations agreed reasonably well with each other, and also with the time obtained from a Rossi time-scale experiment. The neutron bursts produced by the reactor were used in other experiments on delayed neutrons, gamma-rays, the effect of intense radiation on coaxial cable, and on living animals."

<u>ABSTRACT</u>, LA-397

The Dragon Machine



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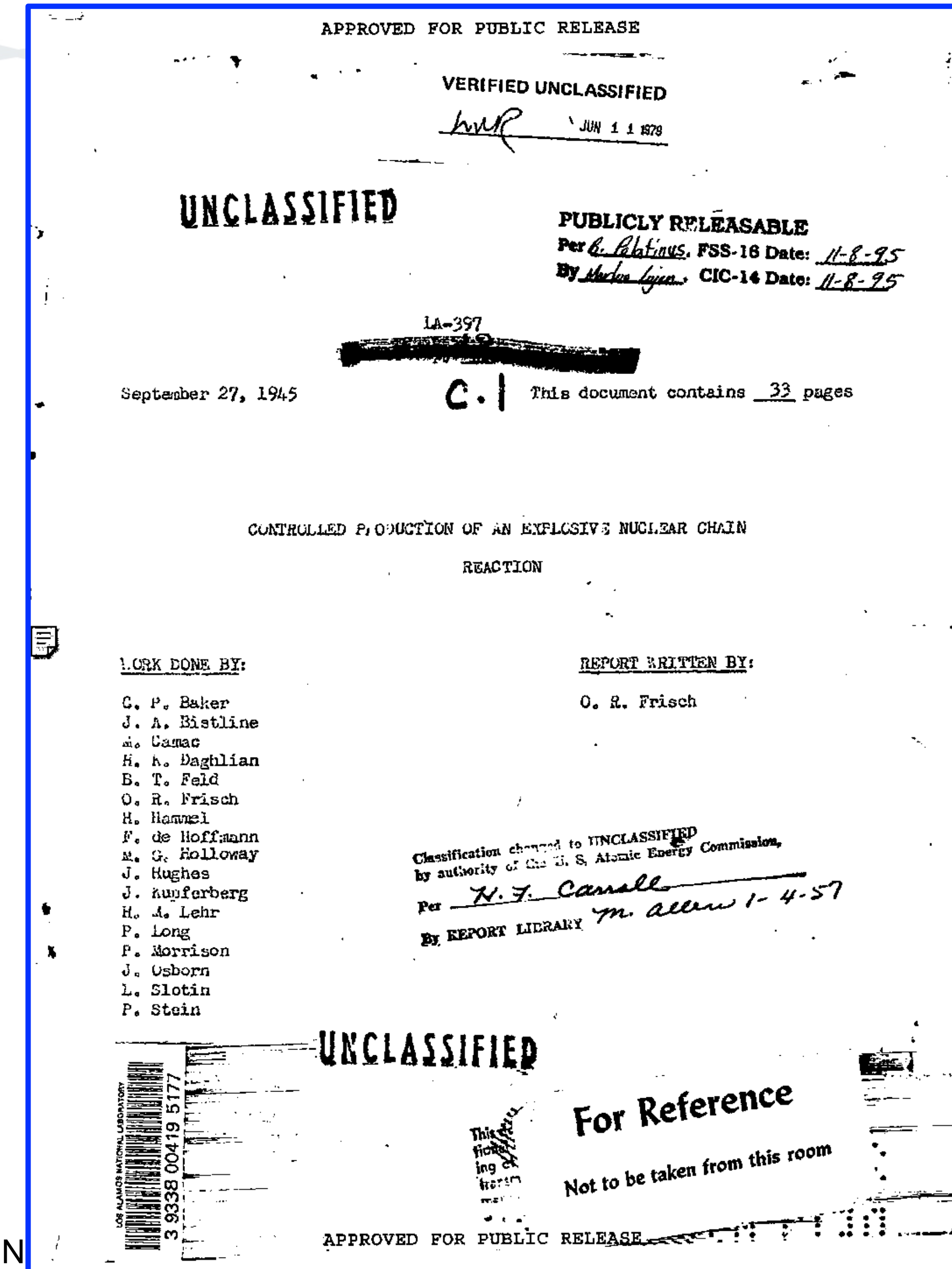
In two excursions the energy release resulted in heating and expansion of the slug causing it to stick in the annulus. The burst was larger than anticipated resulting in personnel radiation exposures of 25 rep – similar in today's units to 25 rad. There were no long-term effects.

Participants in the experiments with the Dragon included:

Otto Frisch
Philip Morrison
Klaus Fuchs
Harry Daghlian
Louis Slotin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Per B. Abatinus, FSS-16 Date: 11-8-95
By Marlon Lujan, CIC-14 Date: 11-8-95

LA-397
[redacted]

September 27, 1945 C.1 This document contains 33 pages

CONTROLLED PRODUCTION OF AN EXPLOSIVE NUCLEAR CHAIN REACTION

WORK DONE BY:

G. P. Baker
J. A. Bistline
M. Camac
H. K. Daghlian
B. T. Feld
O. R. Frisch
H. Hammel
F. de Hoffmann
M. G. Holloway
J. Hughes
J. Kupferberg
H. M. Lehr
P. Long
P. Morrison
J. Osborn
L. Slotin
P. Stein

REPORT WRITTEN BY:

O. R. Frisch

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Per H. F. Carroll
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LOS ALAMOS NATIONAL LABORATORY 3 9338 00419 5177

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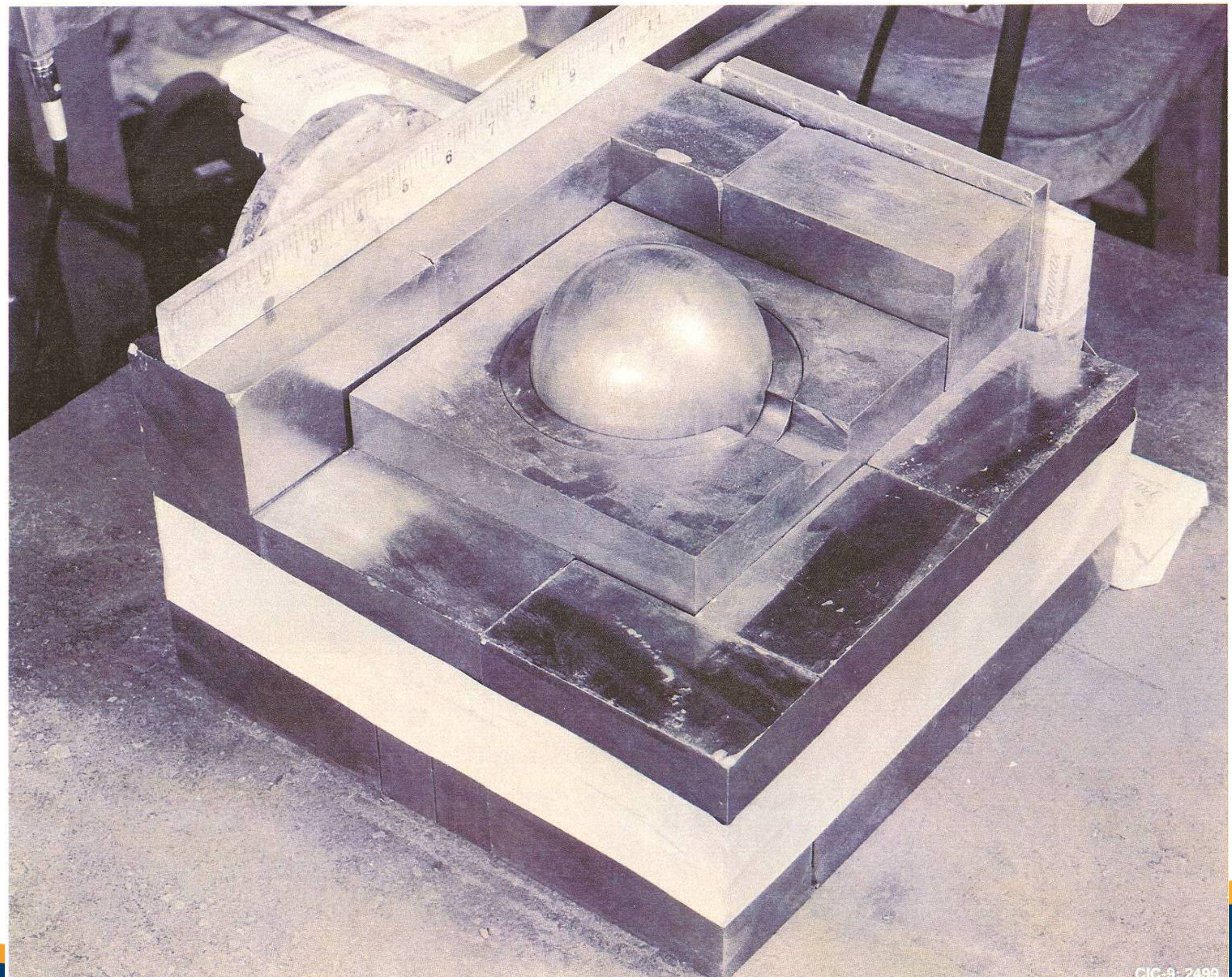
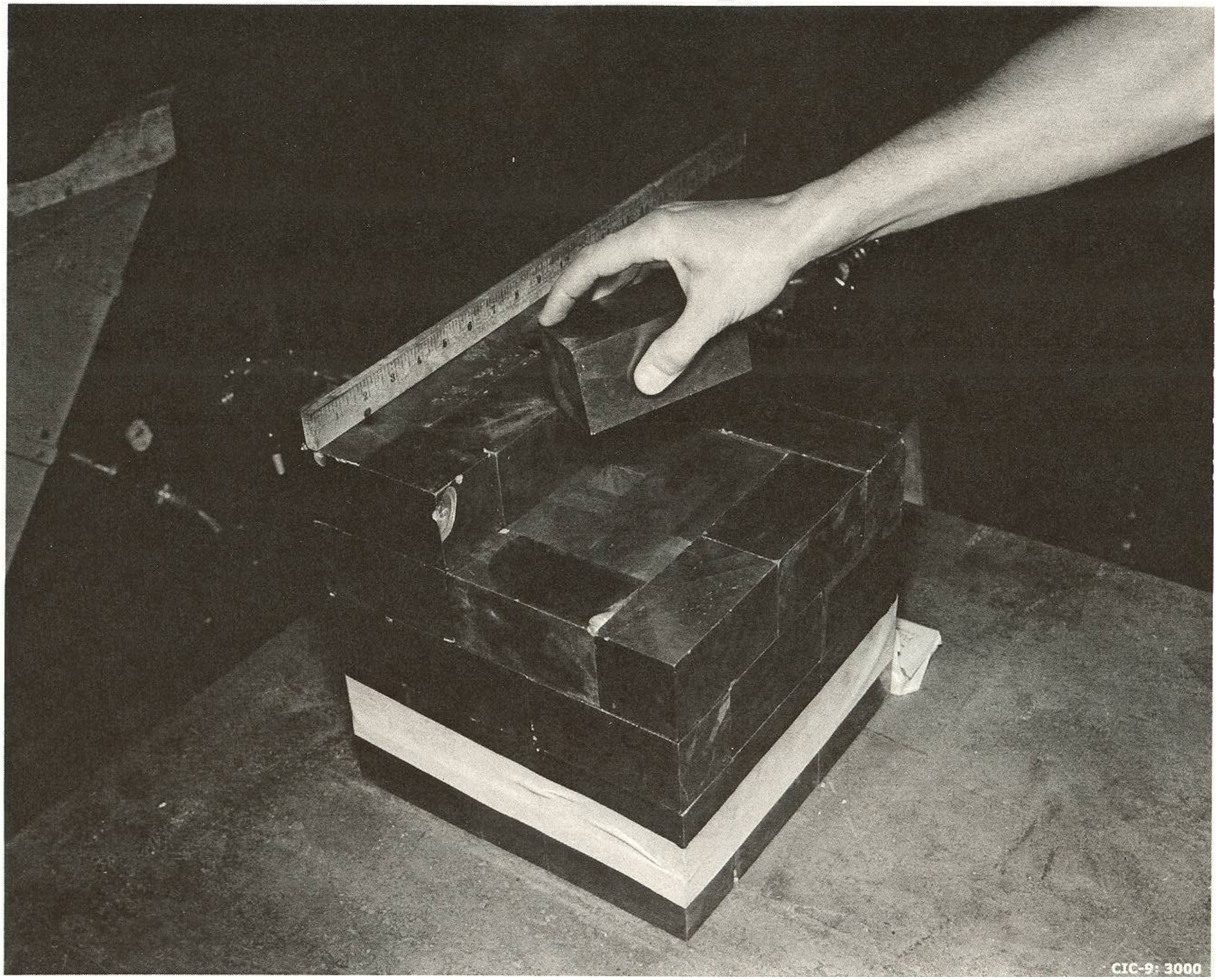
UN

The second accident occurred on August 21, 1945. Harry Daghlian, the sole participant, was working alone, at night, to complete an experiment started earlier in the day. He was stacking tungsten carbide blocks around a plutonium sphere.

The exact details of what happened are not known because the only other person present – the Security Guard - was apparently not actually observing the experiment although he did report a “blue flash”.

The Daghlian Accident – August 21, 1945





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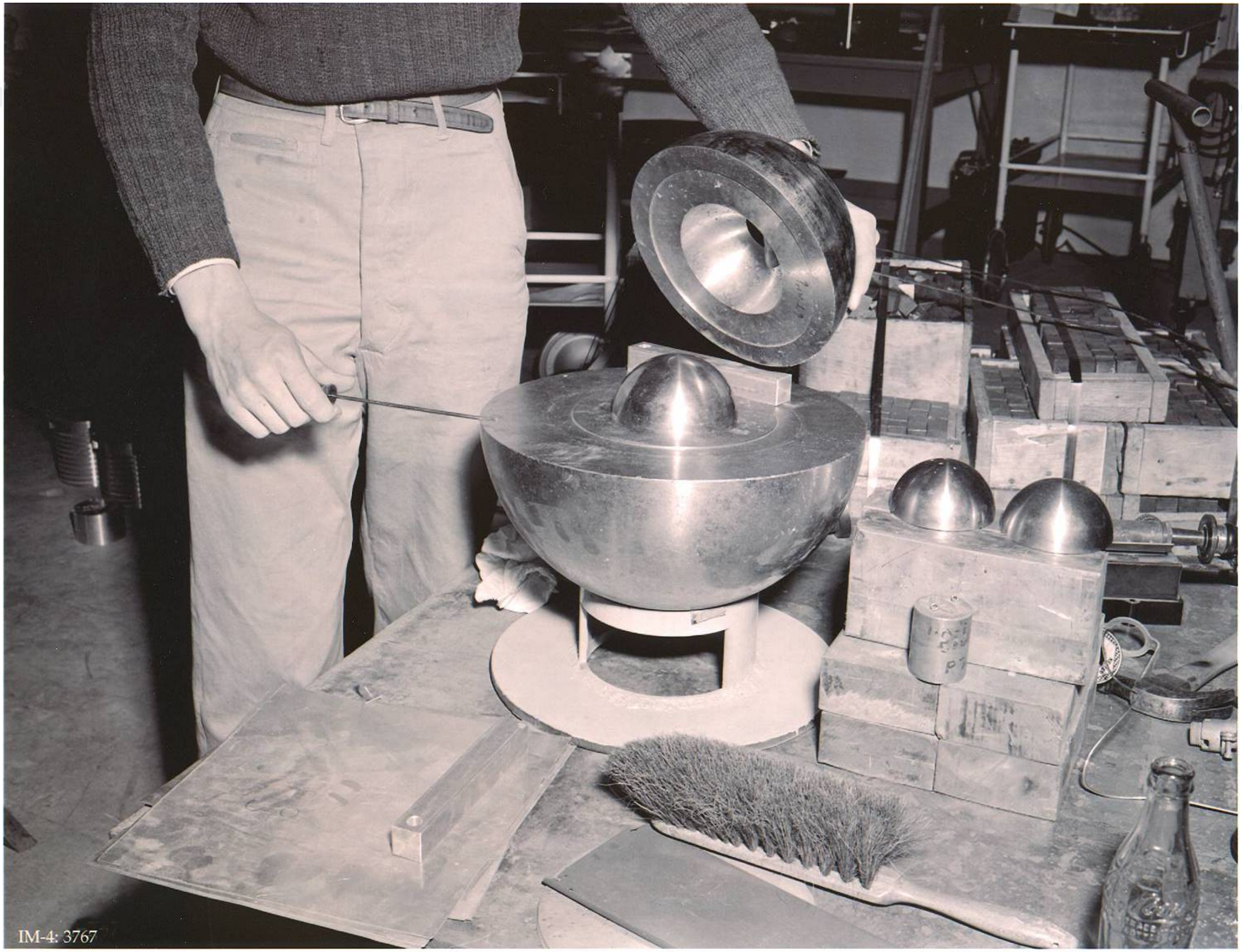
The third accident occurred on May 21,1946 and it involved 8 participants.

Louis Slotin planned to go to the Pacific to participate in nuclear weapons tests. His position at Los Alamos was to be taken by Al Graves. On the afternoon of May 21, 1946 Graves requested a demonstration of the measurement of the “crit.” Slotin agreed and proceeded to lower a hemishell of beryllium on to a plutonium sphere supported in another hemishell of beryllium.

An excursion occurred and the “blue flash” was observed by others in the room.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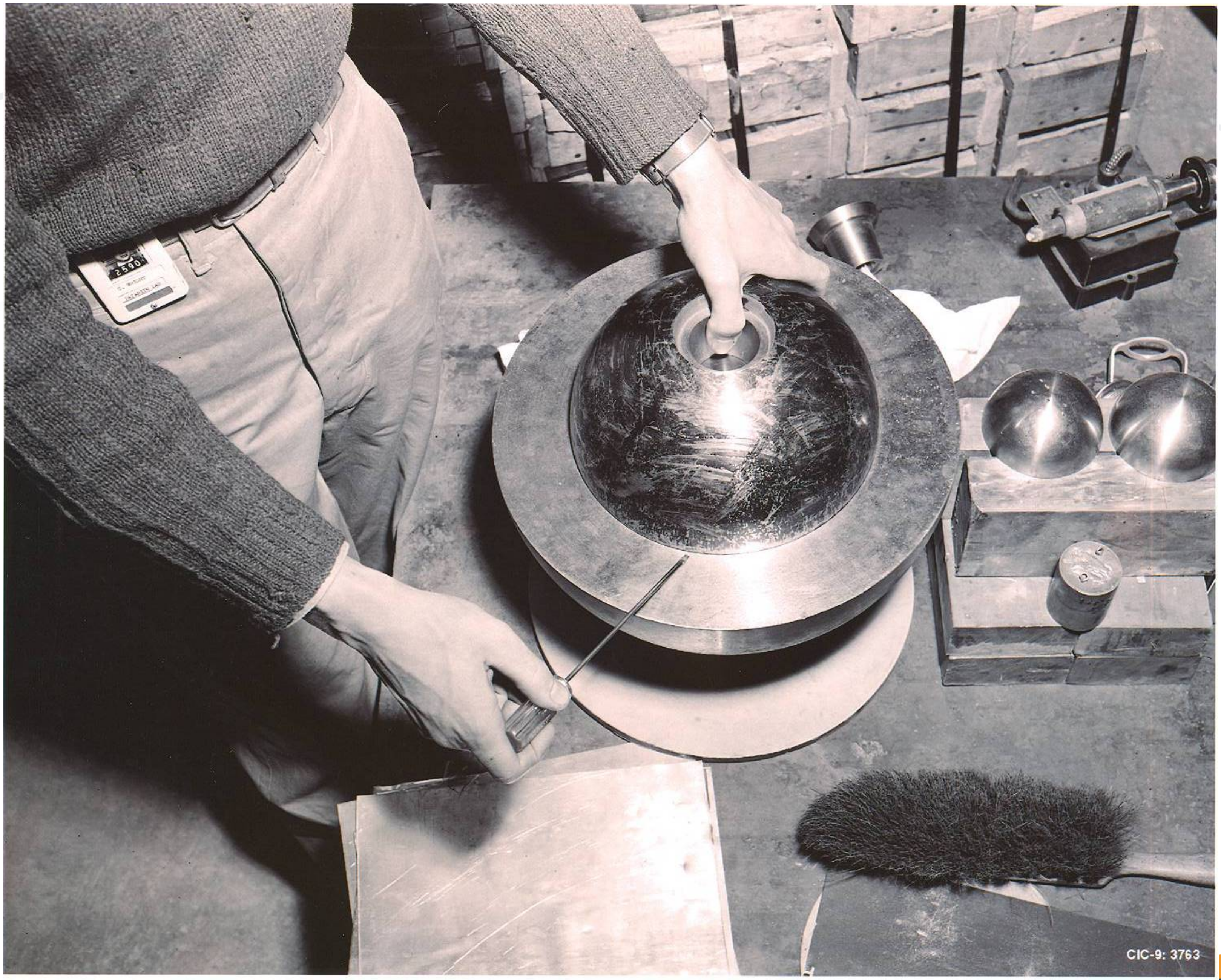

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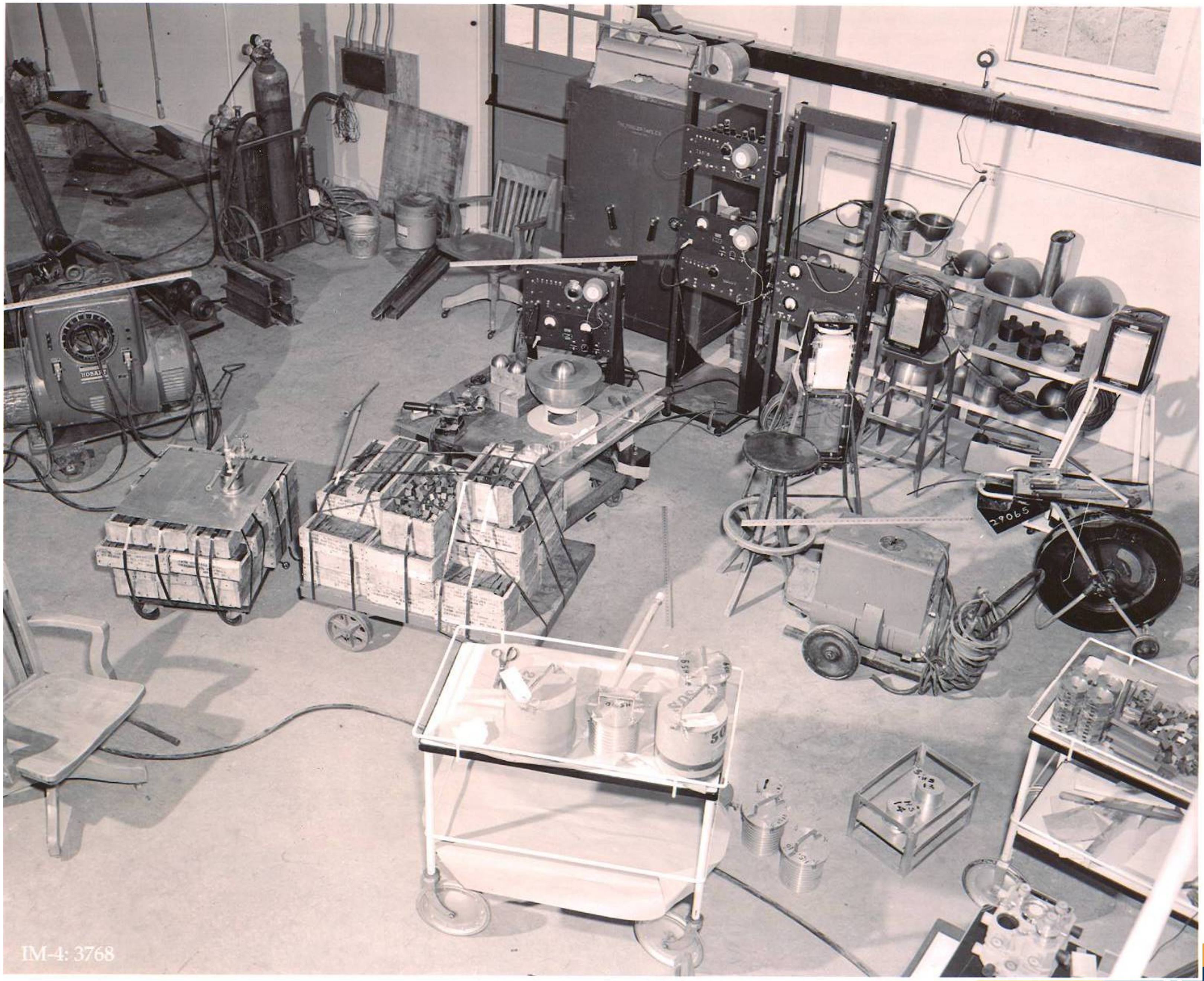

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At this point I would like to make the following observations.

Both Harry Daghlian and Louis Slotin:

- were experienced researchers.
- knew what they were doing.
- were fully aware of the consequences.
- were doing work that they had done before.

However, something went wrong!

Raemer Schreiber was in the room where the accident occurred. He presented the following observations to Darol Froman, Deputy Director, in a memo written on May 28, 1946.

1. Slotin was <u>not</u>, by any possible Interpretation, guilty of what legal minds like to call “criminal negligence.” The monitors were set up and running, an adequate number of observers were present who, by their silence, agreed to the procedure, and he had provided a safety device in the form of wedges to keep the tamper from dropping if it slipped. The fact that this safety device failed does not alter the situation as far as this point is concerned.

2. The assembly was made too rapidly and without adequate consideration of the details of the method. A “dry run” without the active material to check the details of the mechanical operations should have been made.

3. Only those persons actually concerned with the assembly should have remained in the room.

4. No conventional safety devices operating from a neutron monitor could have prevented the accident. The neutron rise was too rapid to have the reaction stopped by any devices that I have seen used at Los Alamos.

5. While operation of such an assembly by remote control would have eliminated the hazard from this particular “burst”, it might well have become a real explosion with equal or greater damage to personnel in spite of shielding walls unless a positive and fast-acting safety device were part of the assembly. In this case, Slotin was that safety device.

Schreiber went on to recommend a list of guidelines.

Although they were specific to the conduct of critical experiments, I believe that they form the basis of nuclear criticality safety to this day.

1. The formulation, approval and publishing of a new set of rules will not prevent more accidents. As stated in item (1) of the preceding section, the existing rules were nominally complied with. In addition to the restatement of rules, there must be a continuous and vigorous campaign to keep the people participating in this work aware of the potential danger in every assembly. Perhaps the work should be rotated among a number of people. As soon as a person ceases to be nervous about the work, he should be transferred to another job.

2. Any new assembly should be planned in detail a considerable time in advance. The plan should be sent to several responsible people, any one of which could veto the plan or ask for a clarification.

3. Every new assembly should be attended by one or more observers whose job would be to stop any procedure which they consider hazardous.

4. Wherever feasible, an assembly should be done by remote control provided that this control incorporates safety devices guaranteed to stop the reaction in the shortest possible time.

5. A complete account of each assembly should be kept, possibly with a running commentary fed into a wire recorder and either a movie camera or an automatic still camera.

6. New critical assemblies should never be reduced to a routine matter to be "run through before lunch."

7. A detailed file of all critical assemblies should be kept up to date. This file would be valuable as a guide in making future assemblies and could also be evidence for removing assemblies known to be safe from the rather severe restrictions which will undoubtedly be imposed on all untried assemblies.

In other words:

Regulations do not prevent accidents - people do.

Study the accidents of the past – to avoid repeating them.

Never take anything for granted!

Keep the law of unanticipated consequences in mind at all times.

I recommend

"The Black Swan", by Nassim Nicholas Taleb (now available in paperback)

"The Limits of Safety", by Scott D. Sagan

"Inviting DISASTER", by James R. Chiles

"A Summary of Accidents and Incidents Involving Radiation in Atomic Energy Activities", June 1945 thru December 1955. D. F. Hayes

LA-13638, "A Review of Criticality Accidents", Thomas P. McLaughlin et. al.

RAK-2. "Accidents in Nuclear Ships", December, 1996, P. L. Olgaard, Riso National Laboratory, DK-4000 Roskilde, Denmark. This document can be Obtained from NKS Secretariat, P.O. Box 49, DK-4000 Roskilde, Denmark.